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THE QUEENSLAND JOURNAL OF AGRICULTURAL SCIENCE

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STUDIES OF PLANT AND SOIL NEMATODES

2. QUEENSLAND HOST RECORDS OF ROOT-KNOT NEMATODES *(MELOIDOGYNE* SPECIES*)*

By R. C. COLBRAN, M.Agr.Sc., Entomologist, Entomology Branch, Division of Plant Industry.

SUMMARY.

Meloidogyne species which have been found in Queensland are M. javanica (Treub) Chitwood, M. arenaria (Neal) Chitwood, M. hapla Chitwood, and M. incognita (Kofoid and White) Chitwood. Within these species there are distinct physiological races.

The records are presented in two sections. In the first the hosts are arranged in alphabetical order with data on nematode parasite, maximum severity of infestation observed, locality, and susceptibility of test plants; in the second the relevant hosts are listed under each of the Meloidogyne species.

The host list includes 269 species in 62 botanical families. Many of these are new records.

I. INTRODUCTION.

In 1949 Chitwood separated the root-knot nematodes from the genus *Heterodera* in which they were considered a single species, *H. marioni* (Cornu) Goodey, and transferred them to the genus *Meloidogyne*. He redescribed *M. exigua* Goeldi, *M. javanica* Treub, *M. incognita* Kofoid and White and *M. arenaria* Neal, and described *M. hapla* and *M. incognita acrita*. The main character on which Chitwood (1949) based the separation of species was the pattern of the striations in the perineal region of adult females.

Earlier, several workers, including Christie and Albin (1944), Christie (1946) and Christie and Havis (1948), had demonstrated that different root-knot nematode populations varied in their plant-host reactions.

Since 1949 the following species and subspecies have been described:— *M. arenaria thamesi* Chitwood 1952, *M. brevicauda* Loos 1953, *M. inornata* Lordello 1956, *M. javanica bauruensis* Lordello 1956, and *M. acronea* Coetzee 1956.

Sasser (1954) studied the host-parasite relationships of populations of *M. javanica, M. arenaria, M. hapla, M. incognita incognita* and *M. incognita acrita,* and proposed that these species could be separated by testing their effects on *Arachis hypogaea* L. (peanut, Spanish); *Citrullus vulgaris* Schrad. (watermelon, Dixie Queen); *Triticum aestivum* L. (wheat, Coastal), *Hordeum vulgare* L. (barley, Moore), or *Zea mays* L. (corn, Golden Cross Bantam); *Capsicum frutescens* L. (red pepper, California Wonder); and *Lycopersicon peruvianum* (L.) Mill. He concluded that peanuts are susceptible to *Meloidogyne hapla* and *M. arenaria* but resistant to the other nematode species; watermelon, wheat, barley and corn are susceptible to *M. arenaria* but resistant or immune to *M. hapla;* red pepper is resistant to *M. javanica;* and *Lycopersicon peruvianum* is susceptible to *M. incognita acrita* but resistant to *M. incognita incognita.*

Subsequently several workers, including Sasser and Nusbaum (1955), Colbran (1955), Linde (1956) and Sauer and Giles (1957), reported nematode populations which differed in plant-host reactions from those originally studied by Sasser (1954). The presence of physiological races within the species makes host testing necessary before resistant crops can be recommended for rotations.

Root-knot nematodes have been proved of considerable economic importance in Queensland, being pests of a number of cultivated crop plants, including tobacco (*Nicotiana tabacum* L.), tomato (*Lycopersicon esculentum* Mill.), pineapple (*Ananas comosus* (L.) Merr.), banana (*Musa* spp.), strawberry (*Fragaria X ananassa* Duch.), carrot (*Daucus carota* L.) and beetroot (*Beta vulgaris* L.).

This paper follows an investigation to determine the species of *Meloidogyne* present in Queensland and their host plants.

II. MATERIAL AND METHODS.

Roots infested with *Meloidogyne* species were preserved in 5 per cent. formalin prior to examination. Mature females were dissected from the roots and the perineal regions removed and trimmed with an oculist's scalpel on a perspex block before being mounted in lactophenol.

Selected *Meloidogyne* populations were increased on tomatoes and tested under glasshouse conditions against the following plants—barley (*Hordeum vulgare* L.), beetroot (*Beta vulgaris* L.), cabbage (*Brassica oleracea* L. var. *capitata* L.) capsicum (*Capsicum frutescens* L.), carrot (*Daucus carota* L.), cauliflower (*Brassica oleracea* L. var. *botrytis* L.), cotton (*Gossypium barbadense* L.), cowpea (*Vigna sinensis* (L.) Endl. ex Hassk.), cucumber (*Cucumis sativus* L.), endive (*Cichorum endivia* L.), French bean (*Phaseolus vulgaris* L.), lettuce (*Lactuca sativa* L.), linseed (*Linum usitatissimum* L.), mung bean (*Phaseolus mungo* L.), oats (*Avena sativa* L.), onion (*Allium cepa* L.), pea (*Pisum sativum* L.), peanut (*Arachis hypogaea* L.), pigeon pea (*Cajanus cajan* (L.) Millsp.), pumpkin (*Cucurbita maxima* Duch.), Rhodes grass (*Chloris gayana* Kunth), rye (*Secale cereale* L.), salsify (*Tragopogon porrifolius* L.), strawberry

(*Fragaria X ananassa* Duch.), sweet corn (*Zea mays* L.), *soybean* (*Glycine max* (L.) Merr.), tobacco (*Nicotiana tabacum* L.), tomato (*Lycopersicon esculentum* Mill.), watermelon (*Citrullus vulgaris* Schrad.), wheat (*Triticum aestivum* L.), and white clover (*Trifolium repens* L.).

III. SPECIES OF *MELOIDOGYNE* PRESENT IN QUEENSLAND.

The following species have been found in Queensland—*M. javanica, M. arenaria, M. hapla* and *M. incognita.* Some of these co-exist, particularly in areas where plants are frequently introduced, such as small-crop farms, home gardens and parks.

Fig. 1.

Left, Healthy strawberry root system. Right, Strawberry root system infected with *Meloidogyne hapla.*

Fig. 2.

Galls from peanut roots inoculated with *Meloidogyne hapla.*

M. javanica, the Javanese root-knot nematode, is the most widely distributed species in Queensland. Crops in which severe root-knot has been recorded include tobacco, pineapple, tomato, banana, carrot and beetroot. The majority of the populations of *M. javanica* studied by the author did not reproduce on red pepper, but several exceptions have been noted.

M. arenaria has been found in a number of localities in the coastal area south of Rockhampton. The most severe infestations occurred on tomato crops. Populations of *M. arenaria* studied in glasshouse tests did not reproduce on peanuts.

M. hapla, the strawberry root-knot nematode, occurs in south-eastern Queensland as a major pest of strawberries. The galls formed by this species are characteristic, being small with radiating lateral rootlets which give the

root system a matted appearance (Fig. 1). The spread of *M. hapla* has been facilitated by the use of infested strawberry runners. Repeated glasshouse tests have shown that peanuts and red pepper are resistant to populations of *M. hapla* infesting strawberries in Queensland. The few galls observed in these tests were typical of those normally formed by this species (Fig. 2).

M. incognita occurs in coastal Queensland, principally in the southern and central districts, where it causes serious galling on lettuce, French bean and tomato. This species is common on tobacco in the Inglewood district. The majority of the populations of *M. incognita* tested did not reproduce on *Lycopersicon peruvianum* (L.) Mill. No populations produced more than a few galls on cotton.

IV. PRESENTATION OF DATA.

The host list is restricted to plants on which mature females and eggs of *Meloidogyne* species were found, and is presented in two parts.

In Section I the hosts are arranged in alphabetical order. The number given in parentheses after each species refers to the botanical family (see Appendix: Key to Botanical Families). An asterisk before the plant name indicates that the species was not recorded as a host by Goodey and Franklin (1956). The nematode species attacking the host are recorded with locality—an X indicates that the infestation was observed only in the glasshouse; maximum infestation as light, moderate or heavy; and the effect of the population, if tested, on selected plants in glasshouse tests. The ratings are 0 no infestation, 1 very light, 2 light, 3 moderate, 4 heavy.

In Section II the plant species are arranged in alphabetical order for each species of *Meloidogyne*.

SECTION I.

HOST-NEMATODE LIST.

**Abutilon oxycarpum* F. Muell. ex Benth. forma *acutatum* Benth.
M. incognita Light. Gayndah.

**Acacia cunninghamii* Hook. (34). Brisbane black wattle.
M. javanica. Moderate. Brisbane.

**Acacia glaucocarpa* Maid. & Blakely (34).
M. incognita. Moderate. Benarkin.

**Acacia myrtifolia* (Sm.) Willd. (34).
M. javanica. Moderate. Beerwah.

**Acacia pugioniformis* Wendl. (34).
M. arenaria. Heavy. The Blunder (Brisbane).
(This population did not reproduce on peanuts.)

**Ageratum houstonianum* Mill. (18). Blue billygoat weed.
M. javanica. Moderate. Wetheron (Gayndah district).

**Alternanthera denticulata* R.Br. (3). Lesser joyweed.
M. javanica. Heavy. Capalaba.

**Alternanthera ficoidea* (L.) R. & S. (3).
M. javanica. Heavy. Woodstock.

**Alternanthera nana* R.Br. (3). Hairy joyweed.
M. incognita. Light. Gayndah.

Fig. 3.
Pineapple Infested with *Meloidogyne javanica.*

Alternanthera repens (L.) Steud. (3). Khaki weed.
M. incognita. Heavy. Gurgeena Plateau (Gayndah district).

Amaranthus paniculatus L. (3). Redshank.
M. incognita. Moderate. Gurgeena Plateau.

Amaranthus tricolor L. (3).
M. incognita. Moderate. Brisbane.

Amaranthus viridis L. (3). Green amaranth.
M. javanica. Heavy. Brisbane.

Anagallis arvensis L. (48). Scarlet pimpernel.
M. incognita. Light. Stanthorpe.

Ananas comosus (L.) Merr. (12). Pineapple (Fig. 3).
M. javanica. Heavy. Coastal Queensland; Mareeba.

Antirrhinum majus L. (53). Snapdragon.
M. javanica. Heavy. Brisbane.

Apium graveolens L. (59). Celery.
M. javanica. Heavy. Brisbane.

**Apium leptophyllum* (DC.) F. Muell. (59). Slender celery.
M. javanica. Moderate. Ormiston.

Arachis hypogaea L. (34). Peanut.
M. hapla. Light. X.

No reproduction has been observed in the field on Red Spanish peanuts. Several small galls were found in the course of repeated inoculation tests with populations of *M. hapla* obtained from strawberries. (Fig. 2.)

**Argemone mexicana* L. (43). Mexican poppy.
M. javanica. Light. Claredale.

**Artanema fimbriatum* Don (53).
M. incognita. Light. Benarkin.

**Asclepias curassavica* L. (7). Red-head cotton bush.
M. javanica. Heavy. Coastal areas south of Gympie.
M. javanica (Mt. Tamborine): beetroot 1, cucumber 4, French bean 2, linseed 0, watermelon 3.

**Asclepias fruticosa* L. (7). Narrow-leaf cotton bush.
M. javanica. Heavy. Coastal areas south of Gympie.

**Aster subulatus* Michx. (18). Bushy starwort.
M. javanica. Moderate. Brisbane.

**Astrophytum myriostigma* Lem. (13).
Meloidogyne sp. Moderate. Brisbane.

**Astrophytum ornatum* (DC.) Weber (13).
Meloidogyne sp. Moderate. Brisbane.

Avena sativa L. (29). Oats.
M. incognita. Light. X.
M. javanica. Light. X.

Begonia semperflorens Link & Otto (9). Begonia.
M. incognita. Heavy. Botanic Gardens, Brisbane.

Beta vulgaris L. var. *vulgaris* (17). Beetroot.
M. incognita. Heavy. Brisbane.
M. javanica. Heavy. Coastal Queensland.

Beta vulgaris L. var. *cicla* L. (17). Silver beet.
M. incognita. Heavy. Brisbane; Charleville; Rockhampton.

M. incognita (Brisbane): capsicum 0, cotton 0, cowpea 4, *Lycopersicon peruvianum* 1, okra 4, peanut 0, tomato 4, watermelon 4.

M. incognita (Charleville): *Lycopersicon peruvianum* 0, tomato 4.
M. javanica. Heavy. Coastal Queensland.

Bidens pilosa L. (18). Cobbler's pegs.
M. javanica. Light. Brisbane, Ormiston.

**Borreria brachystema* (R.Br. ex Benth.) Val. (50).
M. javanica. Heavy. Middle Barrata (Ayr district).

**Brachiaria miliiformis* (Presl.) Chase. (29). Green summer grass.
M. javanica. Light. Claredale.

Brassaia actinophylla F. Muell. (6). Umbrella tree.
M. incognita. Heavy. Brisbane.

Brassica napus L. var. *napobrassica* (L.) Rchb. (21). Swede turnip.
M. javanica. Moderate. Ormiston.

Brassica oleracea L. var. *botrytis L.* (21). Cauliflower.
M. hapla. Light. X.
M. incognita. Light. X.

Brassica oleracea L. var. *capitata* L. (21). Cabbage.
M. hapla. Light. X.
M. incognita. Moderate. Stanthorpe.
M. javanica. Moderate. Ormiston, Mt. Isa.
M. javanica (Ormiston): capsicum 0, *Lycopersicon peruvianum* 2, peanut 0, sweeet corn 1, tomato 4, watermelon 2.

No infestations of economic importance have been recorded from this host.

Cajanus cajan (L.) Millsp. (34). Pigeon pea.
M. incognita. Heavy. Brisbane.
M. javanica. Heavy. Widespread.

Cajanus cajan is resistant to some populations of *M. javanica.*

(*Calendula officinalis* L. (18). Calendula.
M. arenaria. Moderate. Wetheron (Gayndah district).

(**Calotis dentex* R.Br. (18). White burr daisy.
M. incognita. Moderate. Benarkin.

(*Capsicum frutescens* L. (54). Capsicum.
M. arenaria. Moderate. X.
M. hapla. Light. X.
M. incognita. Heavy. X.
M. javanica. Moderate. Ormiston.

Capsicum frutescens is resistant to most races of *M. javanica* and to some races of *M. incognita.*

(*Carica papaya* L. (15). Papaw.
M. javanica. Heavy. Coastal Queensland.
M. javanica (Rochedale): *Lycopersicon peruvianum* 2, peanut 0, sweet corn 0, tomato 4.

(*Cassia mimosoides* L. (34).
M. incognita. Moderate. Brisbane.
M. javanica. Light. Mareeba.

(*Celosia argentea* L. var. *argentea* (3). Cockscomb.
M. javanica and *M. arenaria.* Heavy. Brisbane.

(*Celosia argentea* L. var. *cristata* Kuntze (3).
M. javanica. Heavy. Brisbane.

(**Centratherum muticum* Less. (18).
M. incognita. Moderate. Moggill, Benarkin.

(**Cephalocereus senilis* (Haw.) Pfeiff. (13).
M. incognita. Moderate. Brisbane.

(**Cereus peruvianus* (L.) Mill. (13).
M. incognita. Moderate. Brisbane.

(*Chenopodium album* L. (17). Fat hen.
M. incognita. Moderate. Stanthorpe.

(**Chenopodium carinatum* R.Br. (17). Keeled goosefoot.
M. incognita. Light. Stanthorpe.

(**Chenopodium trigonon* R. & S. (17). Fishweed.
M. incognita. Light. Gayndah.

Chrysanthemum frutescens L. (18). Marguerite daisy.
M. javanica and *M. incognita*. Heavy. Brisbane.

Chrysanthemum maximum Ram. (18). Shasta daisy.
M. incognita. Heavy. Brisbane.

Chrysanthemum spp. (18). Chrysanthemum.
M. incognita. Moderate. Brisbane.

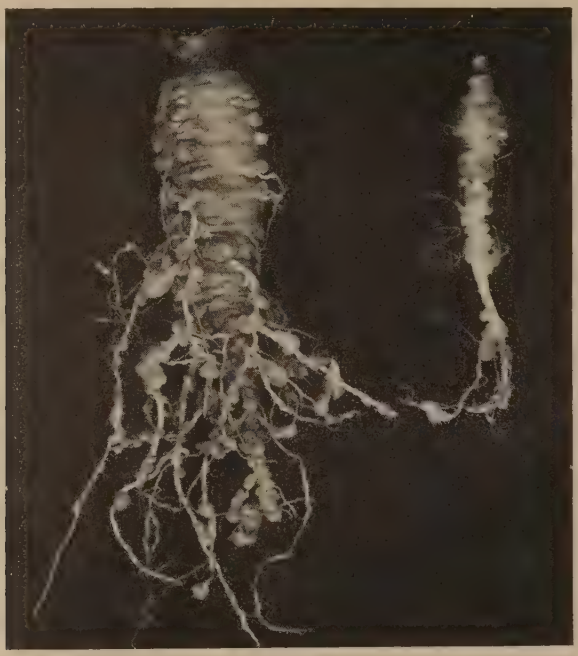

Fig. 4.
Carrot roots infested with *Meloidogyne javanica*.

Cichorium endivia L. (18). Endive.
M. arenaria. Moderate. Warwick.
M. hapla. Moderate. X.

Citrullus vulgaris Schrad. (22). Watermelon.
M. arenaria. Heavy. X.
M. hapla. Light. X.
M. incognita. Heavy. X.
M. javanica. Heavy. X.

Citrus sp. (51). Orange.

M. incognita. Heavy. Wynnum: capsicum 3, cotton 0, cowpea 4, *Lycopersicon peruvianum* 1, okra 4, peanut 0, strawberry 0, tomato 4.

Only one tree has been found severely infested. The variety was Washington Navel and the rootstock sweet orange or citronelle. In glasshouse tests the population produced terminal swellings on *Poncirus trifoliata* (L.) Raff. but no egg masses were observed.

**Cleistocactus strausii* (Heese) Bckbg. (13).

M. incognita. Moderate. Brisbane.

**Cleome aculeata* L. (14).

M. javanica. Light. Kamerunga.

Clerodendrum ugandense Prain (60). Blue Butterfly bush.

M. incognita. Heavy. Brisbane.

**Clitoria ternatea* L. (34). Butterfly pea.

M. javanica. Moderate. Ayr.

Coleus blumei Benth. (33). Coleus.

M. incognita. Heavy. South-eastern Queensland.

M. incognita (Brisbane): capsicum 0, linseed 1, *Lycopersicon peruvianum* 1, tomato 4.

**Corchorus acutangulus* Lam. (57).

M. javanica. Light. Ayr.

**Coronopus didymus* (L.) Sm. (21). Bittercress or lesser swinecress.

M. incognita. Light. Benarkin, Brisbane.

**Crassocephalum crepidioides* (Benth.) S. Moore (18). Thickhead.

M. incognita. Moderate. Moggill.

**Crassula acutifolia* Lam. (20).

M. incognita. Heavy. Brisbane.

**Crassula multicava* L. (20).

M. incognita. Moderate. Brisbane.

**Crassula tetragona* L. (20).

M. incognita. Heavy. Brisbane.

**Crotalaria mucronata* Desv. (34). Streaked rattlepod.

M. hapla. Light. Ormiston.

Cucumis sativus L. (22). Cucumber.

M. hapla. Moderate. X.

M. incognita. Heavy. Brisbane.

M. incognita (Brisbane): capsicum 3, cotton 0, cowpea 3, okra 3, peanut 0, pigeon pea 3, tomato 4.

M. javanica. Heavy. Coastal Queensland.

Cucurbita maxima Duch. (22). Pumpkin.

M. arenaria. Heavy. Tiaro.

M. hapla. Moderate. X.

M. incognita. Heavy. Petrie district.

M. incognita (Lawnton): barley 1, beetroot 0, cabbage 0, capsicum 0, carrot 4, cotton 0, cucumber 3, endive 0, French bean 3, lettuce 2, *Lycopersicon peruvianum* 1, oats 1, onion 0, pea 4, peanut 0, Rhodes grass 0, soybean 2, Sudan grass 0, sweet corn 1, tobacco 4, watermelon 1, wheat 1.

M. javanica. Heavy. South-eastern Queensland.

Cucurbita pepo L. var. *medullosa* Alef. (22). Marrow.

M. arenaria. Heavy. Rockhampton.

**Cyperus brevifolius* (Rottb.) Hassk. (23).

M. incognita. Light. X.

Cyperus rotundus L. (23). Nut grass.

M. javanica. Moderate. Ayr district.

The galls on nut grass are small, and have external egg masses.

Dahlia sp. (18). Dahlia.

M. arenaria. Light. Sunnybank.

M. javanica. Heavy. South-eastern Queensland.

Daucus carota L. (59). Carrot (Fig. 4).

M. hapla. Heavy. Ormiston.

M. incognita. Heavy. Petrie district; Brisbane.

M. javanica. Heavy. Widespread.

M. javanica (Mt. Tamborine): capsicum 0, *Lycopersicon peruvianum* 2, peanut 0, tomato 4, watermelon 4.

**Desmodium muelleri* Benth. (34).

M. javanica. Light. Ayr district.

**Desmodium nemorosum* F. Muell. (34).

M. javanica. Moderate. Atherton Tableland.

**Desmodium rhytidophyllum* F. Muell. ex Benth. (34).
M. incognita. Heavy. Brisbane.
M. incognita (Brisbane): capsicum 3, cotton 0, peanut 0, tomato 4.

**Desmodium trichocaulon* DC. (34).
M. incognita. Moderate. Brisbane.

Desmodium triflorum (L.) DC. (34). Creeping tick trefoil.
M. javanica. Moderate. Kamerunga.

**Desmodium uncinatum* DC. (34).
M. javanica. Moderate. Ormiston.

**Dianella caerulea* Sims (35). Blue flax lily.
M. javanica. Moderate. Palm Beach (South Coast).

**Dianella revoluta* R.Br. (35). A blue berry lily.
M. javanica. Moderate. Eight Mile Plains (Brisbane district).

Dianthus caryophyllus L. (16). Carnation.
M. javanica. Heavy. South-eastern Queensland.
Varietal differences in susceptibility have been observed.

**Digitaria adscendens* (H.B.K.) Henrard (29). Summer grass.
M. javanica. Light. Claredale.

**Digitaria orbata* Hughes (29).
M. arenaria. Moderate. The Blunder (Brisbane).

Digitaria violascens Link (29).
Meloidogyne sp. Light. Beerwah.

Duboisia leichhardtii F. Muell. (54).
M. javanica. Heavy. Nambour.

Duboisia myoporoides R.Br. (54).
M. javanica. Heavy. Nambour.

Echinochloa crus-galli (L.) Beauv. (29). Barnyard millet.
M. javanica. Light. Claredale.

**Echinopsis eyriesii* (Turp.) Zucc. (13).
M. incognita. Moderate. Brisbane.

**Echinopsis multiplex* (Pfeiff.) Zucc. (13).
M. incognita. Moderate. Brisbane.

Eclipta alba (L.) Hassk. (18). White twin heads.
M. javanica. Heavy. Woodstock.

Eleusine indica (L.) Gaertn. (29). Crowsfoot grass.
M. arenaria. Light. Tiaro.
M. javanica. Light. Claredale, Cooroy.

**Emex australis* Steinh. (46). Spiny emex
M. incognita. Light. Gayndah.

Emilia sonchifolia DC. (18). Purple sowthistle.
M. javanica. Light. Ayr.

**Epaltes australis* Less. (18).
M. arenaria. Light. The Blunder (Brisbane).

**Eragrostis elongata* (Willd.) Jacq. (29). Love grass.
M. arenaria. Moderate. The Blunder (Brisbane).

**Erechtites atkinsoniae* F. Muell. (18). Commonwealth weed.
M. incognita. Moderate. Benarkin.

Erechtites quadridentata (Labill.) DC. (18). Cotton fireweed.
M. incognita. Moderate. Benarkin.

Erechtites valerianifolia (Wolf) DC. (18). Brazilian fireweed.
M. javanica. Heavy. Mossman.

**Eriocereus adscendens* (Gurke) Berger (13).
M. incognita. Moderate. Brisbane.

Euphorbia geniculata Orteg. (26).
M. javanica. Heavy. Ormiston.

**Euphorbia officinarum* L. (26).
M. incognita. Heavy. Brisbane.

Euphorbia prostrata Ait. (26). Red caustic creeper.
M. javanica. Moderate. Brisbane.

Ficus carica L. (39). Cultivated fig.
M. incognita. Heavy. Ormiston.
M. javanica. Moderate. Kuraby.

Ficus pumila L. (39). Creeping fig.
M. incognita. Heavy. Brisbane.

**Fimbristylis pauciflora* R.Br. (23).
M. incognita. Moderate. Coolum.

Fragaria X ananassa Duch. (49). Strawberry.
M. hapla. Heavy. South-eastern Queensland.
M. hapla (Ormiston): barley 0, beetroot 1, cabbage 1, capsicum 1, cauliflower 1, cotton 0, cowpea 1, cucumber 0, *Datura stramonium* 0, endive 2, French bean 2, lettuce 3, *Lycopersicon peruvianum* 1, maize 0, mung bean 3, oats 0, onion 0, pea 4, peanut 0, pumpkin 4, Rhodes grass 0, rye 0, salsify 0, sorghum 0, Sudan grass 0, tobacco 4, tomato 3, watermelon 1, white clover 4.

**Fuchsia hybrida* Voss. (41).
M. hapla. Heavy. Ipswich.

Galinsoga parviflora Cav. (18). Potato weed.
M. hapla. Moderate. Redland Bay.

Gerbera jamesoni Bolus (18). Gerbera.
M. incognita. Heavy. South-eastern Queensland.

Gladiolus spp. (31.) Gladiolus.
M. hapla. Moderate. Brisbane.
M. incognita Moderate. Kenmore.

Glycine max (L.) Merr. (34). Soybean.
M. hapla. Moderate. X.
M. incognita. Moderate. X.

**Gnaphalium indicum* L. (18). Cudweed.
M. javanica Light. Eight Mile Plains (Brisbane).

**Gnaphalium japonicum* Thunb. (18).
M. incognita. Moderate. Moggill.

Gomphrena globosa L. (3). Bachelor's buttons.
M. javanica. Heavy. Brisbane.

**Goodenia rotundifolia* R.Br. (28).
M. incognita. Moderate. Benarkin, Moggill.

Gossypium barbadense L. (38). Cotton.
M. incognita. Light. X.
No infestations of root-knot in field cotton have been recorded.

**Graptophyllum pictum* (L.) Griff. (1).
M. javanica. Heavy. Torquay.

**Haworthia tuberculata* Poelln. (35).
Meloidogyne sp. Heavy. Brisbane.

Helianthus annus L. (18). Sunflower.
M. javanica. Moderate. Brisbane.

**Hibbertia linears* R.Br. var. *obtusifolia* (DC.) Benth. (24).
M. incognita. Light. Benarkin.

Hibiscus esculentus L. (38). Okra.
M. arenaria. Heavy. X.
M. incognita var. *acrita.* Heavy. X.
M. incognita. Heavy. X.
M. javanica. Heavy. Ormiston.

Hibiscus sabdariffa L. (38). Rosella.
M. javanica. Moderate. Palmwoods.

Hordeum vulgare L. (29). Barley.
M. incognita. Light. X.

**Hovea acutifolia* A. Cunn. ex G. Don (34). Hovea.
M. javanica. Light. Beerwah.

**Hypericum gramineum* Forst. (30). Small St. John's wort.
M. incognita. Moderate. Brisbane.

Hypochoeris radicata L. (18). Catsear, dandelion, flatweed.
M. incognita. Heavy. Stanthorpe.

**Hyptis capitata* Jacq. (33).
M. javanica. Light. Innisfail.

Impatiens balsamina L. (8). Balsam.
M. incognita. Heavy. Brisbane.
M. incognita and *M. javanica.* Heavy. Buderim.

**Indigofera australis* Willd. (34). Australian indigo.
M. arenaria. Light. Etty Bay (Innisfail).
M. javanica. Heavy. Ormiston.

Indigofera endecaphylla Jacq. (34).
M. javanica. Moderate. Brisbane.

Indigofera hirsuta L. (34). Hairy indigo.
M. javanica. Light. Ormiston.

Ipomoea pes-caprae (L.) Sweet (19). Goatsfoot convolvulus.
M. incognita. Moderate. Palm Beach (South Coast).

**Ipomoea polymorpha* R. & S. (19).
M. javanica. Heavy. Ayr.

Iresine herbstii Hook. f. var. *aureo-reticulata* Hort. (3).

M. incognita. Heavy. Brisbane.

M. incognita (Brisbane): capsicum 3, *Lycopersicon peruvianum* 1, peanut 0, tomato 4.

Iris germanica L. (31). Bearded flag iris.

M. javanica. Heavy. Darra.

**Jacksonia scoparia* R.Br. (34). Dogwood.

M. incognita. Moderate. Moggill.

Fig. 5.

Lettuce roots infested with *Meloidogyne incognita.*

**Juncus polyanthemos* Buchen. (32). Common rush.
M. arenaria. Moderate. The Blunder (Brisbane).

**Jussiaea villosa* Lam. (41). Water primrose.
M. incognita. Heavy. Mourilyan.

**Kleinia repens* (L.) Haw. (18).
M. javanica. Light. Brisbane.

Lactuca sativa L. (18). Lettuce (Fig. 5).
M. hapla. Heavy. X.
M. incognita. Heavy. Brisbane.
M. javanica. Heavy. Brisbane.

Lactuca serriola L. (18). Prickly lettuce.
M. incognita. Light. Lawes.

Lantana camara L. (60). Lantana.
M. javanica. Heavy. Yarwun, Dalrymple Heights (Mackay district).
M. javanica (Dalrymple Heights): *Lycopersicon peruvianum* 0, sweet corn 0, tomato 4, watermelon 4.

**Lantana montevidensis* (Spreng.) Briq. (60). Creeping lantana.
M. incognita. Moderate. Moggill.

**Lepidium hyssopifolium* Desv. (21). Peppercress.
M. incognita. Light. Gayndah.

Lepidium sativum L. (21). Cress.
M. incognita. Heavy. Brisbane.
M. javanica. Heavy. Ormiston.

**Leucas linifolia* Spreng. (33).
M. javanica. Moderate. Kamerunga.

Linum usitatissimum L. (36). Linseed.
M. incognita. Light. X.

**Lobelia purpurascens* R.Br. (37). White-root.
M. incognita. Moderate. Benarkin.

Lupinus angustifolius L. (34). New Zealand blue lupin.
M. incognita. Heavy. Stanthorpe.
M. javanica. Heavy. Ormiston.

Lycopersicon esculentum Mill. (54). Tomato.
M. arenaria. Heavy. Brisbane, Rockhampton.
M. hapla. Moderate. Redland Bay.

M. incognita. Heavy. South-east Queensland; Rockhampton.

M. incognita (Lawes): capsicum 4, cotton 0, *Lycopersicon peruvianum* 1, okra 4, peanut 0, strawberry 0, sweet corn 1.

M. javanica. Heavy. Widespread.

M. javanica (Ormiston): capsicum 0, *Lycopersicon peruvianum* 1, peanut 0, sweet corn 1, watermelon 3.

M. javanica (Howard): beetroot 4, capsicum 0, carrot 3, cotton 0, cucumber 4, *Lycopersicon peruvianum* 2, peanut 0, pumpkin 4, watermelon 3.

M. javanica (Rochedale): capsicum 0, *Lycopersicon peruvianum* 1, peanut 0, sweet corn 1, watermelon 3.

Lycopersicon peruvianum (L.) Mill. (54).

M. arenaria. Heavy. X.

M. hapla. Moderate. Ormiston.

M. incognita. Moderate. X.

M. javanica. Moderate. Ormiston.

Some but not all populations of *M. incognita* failed to reproduce on this plant.

**Macarthuria neocambrica* F. Muell. (2).

M. incognita. Moderate. Coolum.

**Malvastrum spicatum* (L.) A. Gray (38). Malvastrum.

M. incognita. Moderate. Gayndah.

**Mammillaria gracilis* Pfeiff. (13).

M. incognita. Moderate. Brisbane.

Medicago hispida Gaertn. (34). Burr medic.

M. incognita. Heavy. Lawes.

Medicago sativa L. (34). Lucerne.

M. javanica. Moderate. Moggill, Tivoli (Ipswich district).

The infestations recorded here occurred on light sandy alluvial soil adjacent to the Brisbane River.

**Medicago scutellata* (L.) Mill. (34). Snail medic.

M. javanica. Moderate. D'Aguilar.

**Medicago tribuloides* Desr. (34). Barrel medic.

M. incognita. Heavy. Lawes.

**Melochia pyramidata* L. (55).

M. javanica. Light. Ayr.

Mimosa invisa Mart. (34).

M. javanica. Moderate. Innisfail.

**Moghania parviflora* (Benth.) O.K. (34).

M. hapla. Moderate. Tinana Creek.

**Monstera deliciosa* Liebm. (5). Monstera.

M. incognita. Heavy. Brisbane.

This population formed distinct swellings along the roots accompanied by splitting of the outer tissues.

Morus alba L. (39). Mulberry.

M. javanica. Moderate. Charters Towers.

Fig. 6.

Females and egg masses of *Meloidogyne javanica* in a banana root.

Musa spp. (40). Cultivated banana.

M. javanica. Heavy. Coastal Queensland.

M. arenaria. Moderate. Ormiston.

The roots do not always show external swellings but a longitudinal section will reveal numerous adults and egg masses in the cortex (Fig. 6). When large populations are present the roots from the corm remain short with terminal galls.

Nicandra physaloides (L.) Gaertn. (54). Apple of Peru.

M. javanica. Light. Ormiston, Mt. Tamborine.

M. arenaria. Moderate. Tiaro.

Nicotiana glauca Graham (54). Tree tobacco.

M. javanica. Moderate. Claredale.

Nicotiana glutinosa L. (54).

M. javanica. Moderate. X.

Nicotiana tabacum L. (54). Tobacco.

M. arenaria. Heavy. X.

M. hapla. Heavy. X.

M. incognita. Heavy. Inglewood, Tinana Creek.

M. incognita (Inglewood): capsicum 1, cotton 0, *Lycopersicon peruvianum* 1, mung bean 4, okra 4, peanut 0, sweet corn 2, tomato 4.

M. javanica. Heavy. Ayr, Bundaberg, Inglewood, Mareeba.

M. javanica (Ayr.): capsicum 0, cowpea 3, *Lycopersicon peruvianum* 1, peanut 0, sweet corn 2, tomato 4.

**Notocactus ottonis* (Link and Otto) Berg. (13).

M. incognita. Heavy. Brisbane.

**Oenothera longiflora* L. (41). Long-flowered evening primrose.

M. incognita. Light. Stanthorpe.

**Oplismenus imbecillis* R. & S. (29).

M. javanica. Light. X.

The galls were small and had well-filled external egg masses.

**Opuntia elata* Link and Otto ex Salm-Dyck (13).

M. incognita. Moderate. Brisbane.

Oxalis martiana Zucc. (42). Shamrock.

M. javanica. Moderate. Brisbane.

**Pandorea jasminoides* (Lindl.) K.Sch. (10).

M. hapla. Light. Brisbane.

Papaver rhoeas L. (43).

M. incognita. Moderate. Brisbane.

**Parsonsia straminea* (R.Br.) F. Muell. (4). Monkey rope.

M. incognita. Moderate. Moggill.

Passiflora caerulea L. (44).

M. javanica. Moderate. Sunnybank, Ormiston.

Passiflora edulis Sims forma *edulis* (44). Passionfruit.

M. arenaria. Heavy. Rockhampton.

M. incognita. Heavy. Sunnybank.

M. javanica. Heavy. Coastal Queensland.

**Passiflora edulis* Sims forma *flavicarpa* Degener (44).

M. javanica. Light. Ormiston.

This form, which is used as a rootstock for *P. edulis,* shows greater resistance to *M. javanica* than *P. edulis.*

Fig. 7.

Stem galls of *Meloidogyne incognita* on French bean.

**Passiflora maliformis* L. (44).
M. javanica. Moderate. Ormiston.

Passiflora quadrangularis L. (44). Granadilla.
M. javanica. Moderate. Cairns.

**Passiflora suberosa* L. (44). Corky passion-flower.
M. javanica. Moderate. South-eastern Queensland.

Pastinaca sativa L. (59). Parsnip.
M. javanica. Heavy. South-eastern Queensland.

Petroselinum crispum Nym. (59). Parsley.
M. javanica. Moderate. Brisbane.

Petunia hybrida Vilm. (54). Petunia.
M. incognita. Light. Brisbane.

Phaseolus lathyroides L. (34). Phasey bean.
M. incognita. Heavy. Lawes, Beerwah, Coolum.
M. incognita (Coolum): Capsicum 0, cotton 0, French bean 1, *Lycopersicon peruvianum* 1, okra 4, pigeon pea 0, soybean 0, tomato 4.
M. javanica. Heavy. Central Queensland.

Phaseolus mungo L. (34). Mung bean.
M. arenaria. Heavy. X.
M. hapla. Heavy. X.
M. incognita. Heavy. X.
M. javanica. Heavy. Ormiston.

Phaseolus vulgaris L. (34). French bean (Fig. 7).
M. hapla. Moderate. X.
M. incognita. Heavy. Brisbane, Redland Bay, Nambour.
M. incognita (Nambour): capsicum 0, cotton 0, cucumber 4, *Lycopersicon peruvianum* 1, okra 4, peanut 0, pigeon pea 2, sweet corn 0, tomato 4, watermelon 2.

Usually French beans are not adversely affected by root knot although occasional plantings become heavily infested. Stem galls are frequently present for several inches above the crown (Plate 7).

M. javanica. Heavy. Ormiston.

**Physalis minima* L. (54). Wild gooseberry.
M. incognita. Moderate. Claredale.
M. javanica. Moderate. Gayndah.

Physalis peruviana L. (54). Cape gooseberry.
M. javanica. Heavy. Nambour.

Phytolacca octandra L. (45). Inkweed.
M. arenaria and *M. incognita.* Heavy. Brisbane.

**Pimelea pauciflora* R.Br. (56). Poison pimelea.
M. incognita. Moderate. Benarkin.

Pisum sativum L. (34). Pea.
M. hapla. Heavy. X.
M. incognita. Heavy. X.
No field infestations have been recorded.

Fig. 8.
Peach roots infested with *Meloidogyne javanica.*

**Plectranthus australis* R.Br. (33).
M. incognita. Heavy. Moggill.

Podranea ricasoliana (Tanf.) Sprague (10).
M. javanica. Moderate. Brisbane.

Polygonum lapathifolium L. (46). A smartweed.
M. javanica. Moderate. Capalaba.

**Polygonum plebeium* R.Br. (46). Small knotweed.
M. incognita. Light. Stanthorpe.

**Pomax umbellata* Soland. ex Gaertn. (50).
M. incognita. Heavy. Moggill.

Portulaca oleracea L. (47). Pigweed.
M. incognita. Moderate. Brisbane.

Primula obconica Hance (48). Primula.
M. arenaria. Light. Brisbane.

Prunus persica (L.) Batsch (49). Peach.
M. javanica. Heavy (Fig. 8). Stanthorpe district.

Prunus sp. (49). Blood plum.
M. incognita. Heavy. Stanthorpe.

**Pseuderanthemum variabile* (R.Br.) Radlk. (1). Love flower.
M. incognita. Heavy. Moggill.

**Psychotria daphnoides* A.Cunn. ex Hook. (50).
M. incognita. Moderate. Benarkin.

**Pterocaulon glandulosum* F. Muell. (18).
M. javanica. Light. Magnetic Island.

Pterocaulon redolens (Willd.) F. Muell. (18).
M. javanica. Moderate. Claredale.

**Pultenaea villosa* Willd. (34).
M. arenaria. Moderate. The Blunder (Brisbane).
M. incognita. Moderate. Moggill.
M. javanica. Moderate. Beerwah.

Raphanus sativus L. (21). Radish.
M. javanica. Moderate. Rita Island (Ayr district).

**Rhynchelytrum repens* (Willd.) C. E. Hubbard (29). Red Natal grass.
M. arenaria. Light. The Blunder (Brisbane).

Richardia brasiliensis (Moq.) Gomez (50). Mexican clover.
M. javanica. Moderate. Eight Mile Plains, Beerwah.

Rosa sp. (49). Rose.
M. javanica. Moderate. Brisbane.

**Rubus rosifolius* Sm. (49). Native raspberry.
M. incognita. Heavy. Benarkin.

Rumex acetosella L. (46). Sorrel.
M. incognita. Moderate. Stanthorpe.

**Russelia equisetiformis* Schlecht. & Cham. (53). Russelia.
M. incognita. Light. Brisbane.

Saccharum officinarum L. (29). Sugar cane.
M. incognita. Moderate. Bundaberg.
M. javanica. Moderate. Coastal Queensland.

Usually sugar cane is not affected by root-knot nematodes, although damage has occasionally been reported from sandy soils.

Salix alba L. var. *coerulea* (Sm.) Sm. (52). Willow.
M. javanica. Moderate. Ormiston.

Salvia splendens Sello (33). Red salvia.
M. javanica. Light. Brisbane.

Scabiosa caucasica Bieb. (25). Perennial scabious.
M. incognita. Moderate. Brisbane.

Scoparia dulcis L. (53). Scoparia.
M. incognita. Light. Brisbane.

Sechium edule Sw. (22). Choko.
M. javanica. Moderate. Brisbane.

**Sedum rubrotinctum* Clausen (20). Jelly beans.
M. incognita. Heavy. Palm Beach (South Coast).

Senecio cruentus DC. (18). Cineraria.
M. javanica. Light. Brisbane.

Sesbania aculeata Pers. (34). Sesbania pea.
M. incognita. Heavy. Coolum.
M. incognita (Coolum): capsicum 0, *Lycopersicon peruvianum* 1, sweet corn 1.

**Sida cordifolia* L. (38). Flannel weed.
M. arenaria. Moderate. Brisbane.

Sida rhombifolia L. (38). Common sida.
M. javanica. Heavy. South-eastern Queensland.
M. javanica (Ormiston): capsicum 0, *Lycopersicon peruvianum* 1, sweet corn 1, tomato 4, watermelon 3.

Sigesbeckia orientalis L. (18). Indian weed.
M. incognita. Moderate. Moggill, Benarkin.

Sinningia speciosa B. & H. (27). Gloxinia.
M. arenaria. Light. Brisbane.

Solanum auriculatum Ait. (54). Wild tobacco tree.
M. javanica. Moderate. Brisbane.

**Solanum densivestitum* F. Muell. (54).
M. incognita. Moderate. Benarkin.

Solanum melongena L. (54). Egg fruit.
M. javanica. Heavy. Rita Island (Ayr district).

Solanum nigrum L. (54). Blackberry nightshade.
M. incognita. Heavy. Lawes.
M. javanica. Moderate. Coastal Queensland.

**Solanum seaforthianum* Andr. (54). Brazilian nightshade.
M. javanica. Light. Kamerunga.

Solanum stelligerum Sm. (54). Devil's needles.
M. incognita. Moderate. Moggill; Gayndah.

Solanum tuberosum L. (54). Potato.
M. incognita. Heavy. Lawnton.
M. javanica. Heavy. South-eastern Queensland.
(Infested potato tubers have a pimply appearance).

Sonchus oleraceus L. (18). Common sow thistle or milk thistle.
M. arenaria. Moderate. Sunnybank.
M. hapla. Moderate. Ormiston.
M. incognita. Moderate. Stanthorpe.

Stachys arvensis L. (33). Stagger weed.
M. hapla. Moderate. Ormiston.

Stizolobium spp. (34). Velvet beans.
(Varieties: Mucuna, Smith, Somerset, White Stringless, Black Mauritius, Marbilee, Jubilack, White Mauritius).
M. javanica. Light. Ormiston.

**Stylosanthes sundaica* Taub. (34). Townsville lucerne.
M. javanica. Light. Ayr.

**Symphytum peregrinum* Ledeb. (11). Russian Comfrey.
M. javanica. Moderate. Ormiston.

Tagetes erecta L. (18). African marigold.
M. javanica. Light. Brisbane.

Tephrosia candida (Roxb.) DC. (34).
M. javanica. Moderate. Ormiston.

Tragopogon porrifolius L. (18). Salsify.
M. javanica. Moderate. X.

**Trichocereus spachianus* (Lem.) Riccobono (13).
M. incognita. Moderate. Brisbane.

**Trichodiadema barbatum* (L.) Schwantes (2).
M. incognita. Heavy. Brisbane.

Trifolium dubium Sibth. (34). Yellow suckling clover.
M. incognita. Heavy. Kybong (Gympie district).

Trifolium pratense L. (34). Red clover.
M. incognita. Heavy. Gympie, Coolum.
M. incognita (Gympie): capsicum 3, cotton 0, cowpea 4, *Lycopersicon peruvianum* 1, okra 2, peanut 0, tomato 4, watermelon 4.
M. javanica. Heavy. Gympie.

Trifolium repens L. (34). White clover.
M. hapla. Heavy. X.
M. javanica. Heavy. Widespread.

Trifolium subterraneum L. (34). Subterranean clover.

No infestations have been reported from Queensland. Specimens submitted for examinations from Armidale, northern New South Wales, were heavily infested by *M. hapla.*

Triticum aestivum L. (29). Wheat.
M. incognita. Light. X.

**Triumfetta repens* (Bl.) Merr. & Rolfe (57).
M. javanica. Light. Yeppoon.

Tropaeolum majus L. (58). Nasturtium.
M. javanica. Moderate. Brisbane.

Urena lobata L. (38). Urena or pink-flowered Chinese burr.
M. javanica. Moderate. Mossman, Kamerunga.

**Vandasia retusa* (Benth.) Domin (34).
M. javanica. Moderate. Mossman.

**Velleia spathulata* R.Br. (28).
M. javanica. Moderate. Caboolture.

Fig. 9.

Black cowpea infested with *Meloidogyne javanica*.

Verbena bonariensis L. (60). Purple top.
M. arenaria. Moderate. Eight Mile Plains.
M. arenaria (Eight Mile Plains): capsicum 0, okra 4, peanut 0, pigeon pea 0, tomato 4, watermelon 0.
M. incognita. Moderate. Inglewood.

Verbena officinalis L. (60). Common verbena.
M. incognita. Heavy. Lawes.

Vernonia cinerea (L.) Less. (18). Vernonia.
M. incognita. Moderate. Moggill.
M. javanica. Light. X.

Vicia faba L. (34). Broad bean.
M. incognita. Light. Brisbane.

Vigna sinensis (L.) Endl. ex Hassk. (34). (Fig. 9).
M. hapla. Moderate. X.
M. incognita. Heavy. X.
M. javanica. Heavy. Widespread.

Vitis vinifera L. (61). Grape.
M. incognita. Light. Rockhampton, Glen Aplin.

Zea mays L. (29). Maize.
M. incognita. Light. X.
M. javanica. Light. Cooroy.

**Zieria minutiflora* (F. Muell.) Domin (51).
M. incognita. Moderate. Beerwah.

Zingiber officinale Rosc. (62). Ginger.
M. incognita. Moderate. Nambour.

Zinnia elegans Jacq. (18). Zinnia.
M. javanica. Light. Brisbane.

SECTION II.

NEMATODE-HOST LIST.

Meloidogyne arenaria.

Acacia pugioniformis
Calendula officinalis
Capsicum frutescens
Celosia argentea var. *argentea*
Cichorium endivia
Citrullus vulgaris
Cucurbita maxima
Cucurbita pepo var. *medullosa*
Dahlia sp.
Digitaria orbata
Eleusine indica
Epaltes australis
Eragrostis elongata
Hibiscus esculentus
Indigofera australis
Juncus polyanthemos
Lycopersicon esculentum
Lycopersicon peruvianum
Musa spp.
Nicandra physaloides
Nicotiana tabacum
Passiflora edulis forma *edulis*
Phaseolus mungo
Phytolacca octandra
Primula obconica
Pultenaea villosa
Rhynchelytrum repens
Sida cordifolia
Sinningia speciosa
Sonchus oleraceus
Verbena bonariensis

M. hapla.

Arachis hypogaea
Brassica oleracea var. *botrytis*
Brassica oleracea var. *capitata*
Capsicum frutescens
Cichorium endivia
Citrullus vulgaris
Crotalaria mucronata
Cucumis sativus
Cucurbita maxima
Daucus carota
Fragaria X ananassa
Fuchsia hybrida
Galinsoga parviflora
Gladiolus spp.
Glycine max
Lactuca sativa
Lycopersicon esculentum
Lycopersicon peruvianum
Moghania parviflora
Nicotiana tabacum
Pandorea jasminoides
Phaseolus mungo
Phaseolus vulgaris
Pisum sativum
Sonchus oleraceus
Stachys arvensis
Trifolium repens
Trifolium subterraneum
Vigna sinensis

M. incognita.

Acacia glaucocarpa
Alternanthera nana
Alternanthera repens
Amaranthus paniculatus
Amaranthus tricolor
Anagallis arvensis
Artanema fimbriatum
Avena sativa
Beta vulgaris var. *vulgaris*
Beta vulgaris var. *cicla.*

Begonia semperflorens
Brassaia actinophylla
Brassica oleracea var. *botrytis*
Brassica oleracea var. *capitata*
Cajanus cajan
Calotis dentex
Capsicum frutescens
Cassia mimosoides
Centratherum muticum
Cephalocereus senilis
Cereus peruvianus
Chenopodium album
Chenopodium carinatum
Chenopodium trigonum
Chrysanthemum frutescens
Chrysanthemum maximum
Chrysanthemum species
Citrullus vulgaris
Citrus sp.
Cleistocactus strausii
Clerodendrum ugandense
Coleus blumei
Coronopus didymus
Crassocephalum crepidioides
Crassula acutifolia
Crassula multicava
Crassula tetragona
Cucumis sativus
Cucurbita maxima
Cyperus brevifolius
Daucus carota
Desmodium rhytidophyllum
Desmodium trichocaulon
Echinopsis eyriesii
Echinopsis multiplex
Emex australis
Erechtites atkinsoniae
Erechtites quadridentata
Eriocereus adscendens
Euphorbia officinarum
Ficus carica
Ficus pumila
Fimbristylis pauciflora
Gerbera jamesoni
Gladiolus spp.
Glycine max
Gnaphalium japonicum
Goodenia rotundifolia
Gossypium barbadense
Hibbertia linears var. *obtusifolia*
Hibiscus esculentus
Hordeum vulgare
Hypericum gramineum
Hypochœris radicata
Impatiens balsamina
Ipomoea pes-caprae
Iresine herbstii var. *aureo reticulata*
Jacksonia scoparia
Jussiaea villosa
Lactuca sativa
Lactuca serriola
Lantana montevidensis
Lepidium hyssopifolium
Lepidium sativum
Linum usitatissimum
Lobelia purpurascens
Lupinus angustifolius
Lycopersicon esculentum
Lycopersicon peruvianum
Macarthuria neocambrica
Malvastrum spicatum
Mammillaria gracilis
Medicago hispida
Medicago tribuloides
Monstera deliciosa
Nicotiana tabacum
Notocactus ottonis
Oenothera longiflora
Opuntia elata
Papaver rhoeas
Parsonsia straminea
Passiflora edulis
Petunia hybrida
Phaseolus lathyroides
Phaseolus mungo
Phaseolus vulgaris
Physalis minima
Phytolacca octandra
Pimelea pauciflora
Pisum sativum
Plectranthus australis
Polygonum plebeium

Pomax umbellata
Portulaca oleracea
Prunus sp.
Pseuderanthemum variabile
Psychotria daphnoides
Pultenaea villosa
Rubus rosifolius
Rumex acetosella
Russelia equisetiformis
Saccharum officinarum
Scabiosa caucasica
Scoparia dulcis
Sedum rubrotinctum
Sesbania aculeata
Sigesbeckia orientalis
Solanum densivestitum
Solanum nigrum
Solanum stelligerum
Solanum tuberosum
Sonchus oleraceus
Trichocereus spachianus
Trichodiadema barbatum
Trifolium dubium
Trifolium pratense
Triticum aestivum
Verbena bonariensis
Verbena officinalis
Vernonia cinerea
Vicia faba
Vigna sinensis
Vitis vinifera
Zea mays
Zieria minutiflora
Zingiber officinale

M. javanica.

Acacia cunninghamii
Acacia myrtifolia
Ageratum houstonianum
Alternanthera denticulata
Alternanthera ficoidea
Amaranthus viridis
Ananas comosus
Antirrhinum majus
Apium graveolens
Apium leptophyllum
Argemone mexicana
Asclepias curassavica
Asclepias fruticosa
Aster subulatus
Avena sativa
Beta vulgaris var. *vulgaris*
Beta vulgaris var. *cicla*
Bidens pilosa
Borreria brachystema
Brachiaria miliiformis
Brassica oleracea var. *capitata*
Brassica napus var. *napobrassica*
Cajanus cajan
Capsicum frutescens
Carica papaya
Cassia mimosoides
Celosia argentea var. *argentea*
Celosia argentea var. *cristata*
Chrysanthemum frutescens
Citrullus vulgaris
Cleome aculeata
Clitoria ternatea
Corchorus acutangulus
Cucumis sativus
Cucurbita maxima
Cyperus rotundus
Dahlia sp.
Daucus carota
Desmodium muelleri
Desmodium nemorosum
Desmodium triflorum
Desmodium uncinatum
Dianella caerulea
Dianella revoluta
Dianthus caryophyllus
Digitaria adscendens
Duboisia leichhardtii
Duboisia myoporoides
Echinochloa crus-galli
Eclipta alba

Eleusine indica
Emilia sonchifolia
Erechtites valerianifolia
Euphorbia geniculata
Euphorbia prostrata
Ficus carica
Gnaphalium indicum
Gomphrena globosa
Graptophyllum pictum
Helianthus annuus
Hibiscus esculentus
Hibiscus sabdariffa
Hovea acutifolia
Hyptis capitata
Impatiens balsamina
Indigofera australis
Indigofera endecaphylla
Indigofera hirsuta
Ipomoea polymorpha
Iris germanica
Kleinia repens
Lactuca sativa
Lantana camara
Lepidium sativum
Leucas linifolia
Lupinus angustifolius
Lycopersicon esculentum
Lycopersicon peruvianum
Medicago sativa
Medicago scutellata
Melochia pyramidata
Mimosa invisa
Morus alba
Musa spp.
Nicandra physaloides
Nicotiana glauca
Nicotiana glutinosa
Nicotiana tabacum
Oplismenus imbecillis
Oxalis martiana
Passiflora caerulea
Passiflora edulis forma *edulis*
Passiflora edulis forma *flavicarpa*
Passiflora maliformis
Passiflora quadrangularis
Passiflora suberosa
Pastinaca sativa
Petroselinum crispum
Phaseolus lathyroides
Phaseolus mungo
Phaseolus vulgaris
Physalis minima
Physalis peruviana
Podranea ricasoliana
Polygonum lapathifolium
Prunus persica
Pterocaulon glandulosum
Pterocaulon redolens
Pultenaea villosa
Raphanus sativus
Richardia brasiliensis
Rosa sp.
Saccharum officinarum
Salix alba var. *coerulea*
Salvia splendens
Sechium edule
Senecio cruentus
Sida rhombifolia
Solanum auriculatum
Solanum melongena
Solanum nigrum
Solanum seaforthianum
Solanum tuberosum
Stizolobium spp.
Stylosanthes sundaica
Symphytum peregrinum
Tagetes erecta
Tephrosia candida
Tragopogon porrifolius
Trifolium pratense
Trifolium repens
Triumfetta repens
Tropaeolum majus
Urena lobata
Vandasia retusa
Velleia spathulata
Vernonia cinerea
Vigna sinensis
Zea mays
Zinnia elegans

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APPENDIX.

Key to Botanical Families.

1. Acanthaceae
2. Aizoaceae
3. Amaranthaceae
4. Apocynaceae
5. Araceae
6. Araliaceae
7. Asclepiadaceae
8. Balsaminaceae
9. Begoniaceae
10. Bignoniaceae
11. Boraginaceae
12. Bromeliaceae
13. Cactaceae
14. Capparidaceae
15. Caricaceae
16. Caryophyllaceae
17. Chenopodiaceae
18. Compositae
19. Convolvulaceae
20. Crassulaceae
21. Cruciferae
22. Cucurbitaceae
23. Cyperaceae
24. Dilleniaceae
25. Dipsacaceae
26. Euphorbiaceae
27. Gesneriaceae
28. Goodeniaceae
29. Gramineae
30. Hypericaceae
31. Iridaceae
32. Juncaceae
33. Labiatae
34. Leguminosae
35. Liliaceae
36. Linaceae
37. Lobeliaceae
38. Malvaceae
39. Moraceae
40. Musaceae
41. Onagraceae
42. Oxalidaceae
43. Papaveraceae
44. Passifloraceae
45. Phytolaccaceae
46. Polygonaceae
47. Portulacaceae
48. Primulaceae
49. Rosaceae
50. Rubiaceae
51. Rutaceae
52. Salicaceae
53. Scrophulariaceae
54. Solanaceae
55. Sterculiaceae
56. Thymeliaceae
57. Tiliaceae
58. Tropaeolaceae
59. Umbelliferae
60. Verbenaceae
61. Vitaceae
62. Zingiberaceae

FURTHER OBSERVATIONS ON THE EXPERIMENTAL INFECTION OF PIGS WITH *LEPTOSPIRA HYOS* SAVINO AND RENELLA

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SUMMARY.

Five sows inoculated intramuscularly with L. hyos **showed agglutinins and excreted Leptospira in the urine. No clinical abnormality attributable to infection with** L. hyos **was observed.**

Of 58 piglets produced by the five infected sows, 5 were mummified and 6 were born dead. No Leptospira were isolated from the dead piglets.

I. INTRODUCTION.

In a previous paper, Tammemagi and Simmons (1956) reported observations made on four pregnant sows experimentally infected with a strain of *Leptospira hyos*. The aim of their experiments was to show whether infection with *L. hyos* during pregnancy had any effect on the litter. The results obtained were inconclusive but further experiments were considered to be warranted.

This paper reports observations made on another five pregnant sows experimentally infected with a different strain of *L. hyos*.

II. METHODS.

The methods were the same as used previously (Tammemagi and Simmons 1956), except that a different strain of *L. hyos* was used. This strain was isolated from porcine urine obtained from a pig in a commercial piggery. Ten millilitres of urine was centrifuged and the deposit injected intraperitoneally into a guinea pig. The guinea pig was killed six days later and the liver and kidney ground with sterile sand and saline. This tissue suspension was inoculated into a guinea pig, which had a temperature of 104·6 deg. F. six days after inoculation. Heart blood was taken on the same day on which pyrexia occurred and inoculated into several tubes of Schuffner's medium. These inoculated tubes were incubated at 36 deg. C. for 39 days, when one was distributed into several $\frac{1}{4}$ in. diameter Pyrex test tubes, which were sealed. The sealed cultures were held at room temperature for 73 days, when one was opened and the contents sown into 5 ml. Schuffner's medium. After 13 days' incubation at 30 deg. C., numerous Leptospira were present. About 2 ml. sterile Schuffner's

medium was added and this diluted culture was used to inject five pregnant sows intramuscularly with 1 ml. each. Agglutinin absorption tests showed that the strain isolated was *L. hyos*.

All sows were examined daily and rectal temperatures recorded twice daily. Urine samples were collected twice each week from the control and daily from the inoculated sows.

III. RESULTS.

(1) Control Sows.

Table 1 gives details of gestation periods and litters of control and inoculated sows. The four control sows produced 46 piglets, three of which were stillborn. One sow farrowed after a gestation period of 116, two after 117 and one after 119 days. Duration of farrowing was not observed, as all four farrowed during the night.

Table 1.

GESTATION PERIODS AND LITTERS OF INOCULATED AND CONTROL SOWS.

Sow No.	Stage of Pregnancy When Inoculated. (Days.)	Gestation Period. (Days).	No. of Piglets.		
			Born.	Born Dead.	Survived Two Days.
37	84	117	16	2	13
149	110	116	13	5 (3 mummified)	6
154	86	116	10	0	9
199	61	116	9	3 (2 mummified)	6
202	25	119	10	1	8
188	..	117	12	0	10
190	..	117	11	1	10
192	..	119	13	2	11
198	..	116	10	0	9

Urine samples collected from the sows during the experiment were all negative for Leptospira and no agglutinins to *L. hyos* were detected in blood samples taken from the sows or piglets.

(2) Inoculated Sows.

(a) Sow No. 37.

This sow was inoculated 84 days after mating.

Leptospiruria commenced 20 days after infection and occurred on 12 subsequent days with negative samples interspersed (Fig. 1). The last positive sample was obtained on the 73rd day after infection. Leptospira were never numerous and were often dead and misshapen.

The first serum sample, taken seven days after inoculation, had a titre of 1/100 to *L. hyos*. This rose to 1/1000 on the 28th day, and then fell to 1/100 on the 145th day after inoculation (Table 2).

The temperature of the sow was between 99 and 102 deg. F. for 37 days after inoculation, after which an occasional rise of the afternoon rectal temperatures accompanied by slightly reduced appetite was noted on days coinciding with high air temperatures.

Table 2.

RESULTS OF AGGLUTINATION TESTS ON SERA FROM INFECTED SOWS.

Sow No.	Days After Inoculation.								
	7.	14.	28.	42.	56.	70.	84.	105.	145.
37 ..	100*	300	1,000	1,000	1,000	1,000	300	300	100
149 ..	30	300	1,000	1,000	300	300	300	300	†
154 ..	100	300	1,000	1,000	1,000	300	300	100	30
199 ..	30	100	1,000	1,000	1,000	1,000	1,000	300	100
202 ..	100	100	300	300	300	300	300	100	‡

KEY: * Reciprocals of titres. Read at approximately 50% agglutination.
† No agglutination.
‡ No sample.

After a gestation period of 117 days, 14 live and two dead piglets were born over a period of two hours. Leptospiruria occurred prior and subsequent to farrowing. No abnormality was seen in the two dead piglets.

No Leptospira were demonstrated by culture, guinea pig inoculation or histological examination of the liver and kidney of the stillborn piglets or of those that died later from overlaying or as a result of haemorrhage caused by blood collection from the anterior vena cava.

All live piglets were bled before suckling and no agglutinins to *L. hyos* were present.

The sow, when slaughtered five months after inoculation, showed several subcapsular, pinhead-sized, greyish foci in both kidneys. On histological examination, these foci were seen to consist of accumulations of lymphocytes. Occasional foci of a similar type were also present in the deeper cortex and in the medulla. No Leptospira were seen in the kidney sections.

(b) Sow 149.

This sow was inoculated 110 days after mating. Leptospira appeared in the urine on the 21st day after infection and the last positive sample was obtained on the 42nd day (Fig. 1). Altogether, eight of the daily samples were positive within this period. Leptospira were never numerous and were mainly non-motile forms.

Seven days after infection the serum titre to *L. hyos* was 1/30, and after 28 days was 1/1000. Serum collected on the 145th day after infection showed no agglutinins to *L. hyos* (Table 2).

Temperatures recorded included some that were between 104 and 105·4 deg. F. This applied especially to the afternoon temperatures and appeared to occur on those days when the air temperature was also high. Panting was pronounced on these days.

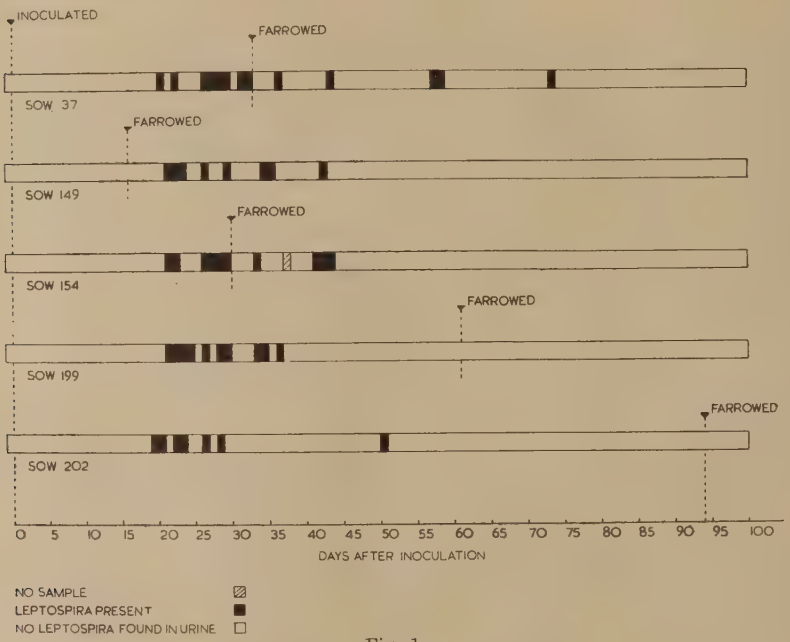

Fig. 1.

Examination of Urine for Leptospira.

Slight constipation with passing of dry faeces and inappetence lasting for several days were noticed over a period of three weeks following farrowing.

Farrowing occurred during the night after a gestation period of 116 days. Leptospiruria commenced five days after farrowing. The litter included eight live and five dead piglets. Three of the five dead piglets were mummified and weighed 1·0, 1·3, and 1·5 oz. respectively. One stillborn piglet weighing 1·5 lb. showed an excess of slightly bloodstained fluid in the thoracic and abdominal cavities and one weighing 1·3 lb. was decomposed.

The weights of the live piglets ranged from 2·5 to 3·6 lb.

Of the live piglets, one died within 24 hours of birth and one within 48 hours. On post-mortem, the former piglet showed five sharply defined

bright red areas on the surface of the liver. These areas were 3–10 mm. in diameter and about 3 mm. deep. The lungs, kidneys and edges of the liver lobes were congested.

Histological examination showed congestion of the liver with dilatation of sinusoids and portal vessels and some fragmentation of the portal cells. In the red areas mentioned above the hepatic cells had undergone liquefaction necrosis and the resulting spaces had filled with red blood cells, together with cellular debris, Kupfer cells, polymorphs and some mononuclear cells. Bile duct proliferation was prevalent throughout.

The piglet that survived 48 hours showed bruising under the throat and the lower jaw. Death was attributed to overlaying.

No Leptospira were demonstrated in any of the dead piglets by histological examination, culture or guinea pig inoculation. The three mummified foetuses were not examined.

Agglutination tests done on sera collected from the piglets the day after farrowing showed agglutinins for *L. hyos.*

The sow was slaughtered five months after infection. No gross abnormalities were seen and no Leptospira were detected by histological examination of kidney tissue.

(c) Sow 154.

This sow was inoculated 86 days after mating.

Leptospiruria was first detected on the 21st day after infection and last observed on the 43rd day (Fig. 1). The urine samples showed Leptospira on 10 days during this period. No sample was obtained on one day.

The serum titre was 1/100 when the sow was bled seven days after inoculation, rose to 1/1000 on the 28th day, and was 1/30 when the sow was slaughtered 145 days after inoculation (Table 2).

The sow showed no clinical evidence of ill-health apart from slight inappetence over a period of seven days immediately after farrowing. The sow's temperature varied from 99 to 104 deg. F. for most of the period of observation, with an occasional temperature above 104 deg. F. being recorded on afternoons of particularly hot days. The highest recorded was 105·6 deg. F. on the 66th day after infection.

Farrowing, which occurred after a gestation period of 116 days, lasted one hour. Leptospiruria occurred before and after farrowing.

Ten live piglets were produced. Nine of these were well developed, weighing 3·0–3·9 lb. The tenth piglet, weighing 2·1 lb., was crushed by the sow one day after birth. No Leptospira were isolated by culture or guinea pig inoculation from liver, lung or kidney tissue of this piglet. Serum obtained from the 10 piglets after they had suckled all showed agglutinins to *L. hyos.*

After slaughtering, no abnormality was seen in the sow, and no Leptospira were detected on histological examination of kidney sections.

(d) Sow 199.

This sow was inoculated 61 days after mating. Leptospiruria commenced on the 21st day and the last positive sample was collected on the 36th day. The urine showed Leptospira on 10 days during this period.

Seven days after inoculation the serum agglutinated *L. hyos* at a dilution of 1/30; the titre rose to 1/1000 on the 28th day. The last sample taken 145 days after infection had a titre of 1/100 (Table 2).

Frequent afternoon temperatures of more than 104 deg. F. were recorded, usually recurring on days of high atmospheric temperature. No ill-health was noted.

Farrowing occurred after a gestation period of 116 days, 19 days after the cessation of leptospiruria.

Six live and three dead piglets were born during the night. Two of the three dead piglets were mummified and each weighed approximately 0·5 lb. The third dead piglet, weighing 2·8 lb., was partly covered with foetal membranes and on post-mortem showed some degree of decomposition. The thoracic and abdominal cavities were filled with blood and the hindquarters were severely bruised. The lungs were not inflated and the stomach was filled with brown mucus. No Leptospira were isolated by culture or by guinea pig inoculation from stomach contents, liver or kidney.

All six surviving piglets showed agglutinins to *L. hyos* when bled on the day of farrowing. The piglets had suckled before being bled.

The sow was slaughtered five months after infection. The only gross macroscopic abnormality was several lesions in the kidneys similar to those in Sow 37. Histological examination showed that these lesions were also accumulations of lymphocytes. No Leptospira were seen in the kidneys.

(e) Sow 202.

This sow was inoculated 25 days after mating. Leptospiruria was first detected 19 days after inoculation and the last positive urine sample was collected on the 50th day. Leptospira were seen in only seven samples during this period.

The serum titre was 1/100 on the seventh day after inoculation and rose to 1/300 on the 28th day. However, the titre was still 1/100 145 days after inoculation (Table 2).

The temperature of the sow was between 99 and 103 deg. F. until she farrowed on the 94th day after infection. During the following four weeks, most of the afternoon temperatures ranged from 103 to 105·2 deg. F. These high temperatures occurred on days of high air temperatures. On a few

occasions, the morning temperatures of the sow were also high, but she showed no evidence of ill-health. Ten days before farrowing, the sow developed a slight lameness of the left hind leg and walked stiffly. This lameness disappeared a few days after farrowing.

Farrowing, which lasted 1½ hours, occurred after a gestation period of 119 days. Leptospiruria had ceased 44 days previously. Nine live and one dead piglet were produced. The dead piglet was not fully developed and was slightly decomposed. No Leptospira were isolated by culture or guinea pig inoculation from stomach contents, liver or kidneys. One of the live piglets was killed by the sow soon after birth. No Leptospira were isolated from the liver, lung or kidney tissue of this piglet by culture or by guinea pig inoculation.

All nine piglets had serum agglutinins to *L. hyos* after suckling.

IV. DISCUSSION.

The results described above are similar to those reported by Ryley and Simmons (1954) and Tammemagi and Simmons (1956) in that infection of pregnant sows with *L. hyos* did not result in abortion, death of piglets or poor breeding performance.

The five sows did not exhibit, at any time during the period of observation, any symptoms referable to the *L. hyos* infection.

Circumscribed haemorrhages in the liver of one piglet and small lesions in the kidneys of two sows were the only abnormalities seen. These lesions were not considered to be the result of *L. hyos* infection. The small lesions in the sow's kidneys were suggestive of being leucotic in origin. According to Englert (1955) leucosis in pigs is often inapparent macroscopically, but histologically foci of lymphocytic aggregations can be seen in various organs.

The excretion of Leptospira by the five sows was even less marked than previously reported (Tammemagi and Simmons 1956). The relatively short period of leptospiruria, the few and abnormal organisms excreted, and the intermittent character of excretion revealed in these results, suggest that diagnosis of this infection by urine examination is not very efficient. However, this procedure must remain an important diagnostic method because alternative methods are equally unsatisfactory.

The serum titre results were similar to those obtained previously (Tammemagi and Simmons 1956) and emphasise that the very high titres of 1/10,000 or more commonly reported in other leptospiral infections are not usual in *L. hyos* infection of pigs. The presence of agglutinins in sera from three of four sows on the 145th day after infection suggests that results of agglutination tests must be interpreted with caution when assessing whether disease present at time of sampling was the result of *L. hyos* infection. Retesting of pigs showing no or low titres about 14 days after first sampling may be of value, for the appearance of titre or an increase in titre could be taken as indicative of active *L. hyos* infection.

The failure to recover Leptospira from the piglets cultured at or within a few days of birth indicates that infection of the foetus is not usual.

Kemenes (1956) reported *L. hyos* as occasionally causing abortion in pigs, and field evidence in Queensland supports this. However, there is no evidence from the experiments reported here to suggest that *L. hyos* does cause abortion or neonatal loss when it infects the pregnant sow.

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CHROMOBACTERIUM VIOLACEUM INFECTION IN A PIG

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SUMMARY.

A Chromobacterium **was isolated on 10% sheep's blood agar and McConkey agar from abscesses in the lung, liver and mammary region and also from the swollen mediastinal lymph nodes of a pig. This organism grew at 25 or 37 deg. C. but not at 4 deg. C. It was haemolytic and produced a violet pigment on blood agar. Gelatin and Loefflers media were liquefied. In liquid media a pale violet pellicle was formed. The organism was pathogenic for mice and mildly pathogenic for guinea pigs.**

Three other strains biochemically and morphologically similar to the pig strain and with similar pathogenicity for guinea pigs and mice were recovered from muddy water.

The nomenclature of this species is discussed. Our strains appear to fit most closely with Chr. violaceum **var.** manilae.

I. INTRODUCTION.

It is generally believed that the chromobacteria are not pathogenic. Wilson and Miles (1954) did not record any pathogens amongst the species described by them. However, Woolley (1904) isolated a strain causing death of carabao in Manila, and in Louisiana, Schattenberg and Harris (1942) recorded "a definite and rapidly fatal infection of the human subject with *Chromobacterium violaceum* var. *manilae*." Sneath, Whelan, Bhagwan Singh and Edwards (1953) described a fatal pyaemia in a soldier caused by a similar organism. These authors stated that from 1904 until 1952, 13 cases were recorded in man. Of these, eight died, two recovered and in three the outcome was not stated.

Seppel, Medina and Atwood (1954) isolated a strain from pigs in Georgia and showed their strain to be pathogenic for guinea pigs, mice and pigs. The strain isolated by us was from extensive lesions in the viscera of a pig. Other strains isolated from muddy water were pathogenic for mice and guinea pigs.

II. EXAMINATION OF SPECIMEN.

The viscera and mammary tissue from a young sow killed at a Townsville slaughterhouse were submitted to the laboratory by Mr. K. C. Beaumont for examination. The mediastinal lymph nodes were enlarged. There were numerous small abscesses about 3 mm. in diameter in the lungs, which also contained a few larger abscesses. Abscesses up to 2 cm. across were distributed throughout the liver. The larger liver and lung lesions had firm, light-cream, caseous centres. The border of this caseous material was conspicuously crenated. In the mammary tissue the lesions consisted of abscesses containing semi-fluid pus.

Microscopically, the lesions were characterised by a subacute inflammatory response. In the sections from affected tissue round cells were the dominating infiltrating elements. Macrophages and plasma cells were evident. In only limited areas was there any gross accumulation of polymorphs. As is common in abscesses in pig tissues, eosinophils were evident.

A gram-negative bacillus was isolated on 10% sheep blood agar and McConkey agar. Strains were obtained from mammary tissue lesions, lung abscesses, mediastinal lymph node and liver abscess.

III. DESCRIPTION OF THE ORGANISM.

Growth Characteristics.—After 24 hours at 37 deg. C. in an aerobic atmosphere, the colonies on 10% sheep blood agar were purple, hemispherical, smooth with a glistening surface and about 1 mm. in diameter. There was haemolysis around the colonies. The colony form was similar on McConkey agar, 5% glycerol agar and nutrient agar. On further incubation for several days, the colony form was the same but colony size increased to about 4 mm. diameter. There was no growth on "Difco" S.S. agar. Nutrient broth after 24 hours' growth showed turbidity with the formation of a purple surface pellicle. On further incubation, the turbidity increased and after a few days a fine white powdery sediment formed at the bottom of the medium. The purple pigment was soluble in alcohol but insoluble in water and chloroform.

Morphology.—The organism was a gram negative, non acid-fast bacillus, approximately 0·5μ wide and 1–2μ long. In young cultures some organisms showed bipolarity. No spores or capsules were formed. It was motile usually with a single polar flagellum and occurred singly or in short chains.

Atmospheric Requirements.—Good growth occurred on 10% sheep's blood agar, aerobically and anaerobically. No pigment was produced anaerobically but it rapidly developed when the cultures were exposed to air.

Temperature Requirements.—On 10% sheep's blood agar growth was good at 25 deg. C., 30 deg. C., and 37 deg. C. During the first 24 hours' growth, colony formation was noticably larger at 37 deg. C. There was no growth at 4 deg. C.

Biochemical Reactions.—In the carbohydrates routinely used in our diagnostic work, acid but no gas was produced from:—

Glucose after 24 hours at 37° C.

Sucrose after 48 hours.

Lactose and mannite after several days.

Maltose was not fermented.

The organism reduced methylene blue and nitrate and produced hydrogen sulphide, ammonia and catalase. It liquefied Loefflers medium and gelatin.

Methyl red, Voges-Proskauer, indole and urease tests were negative.

Litmus milk was acidified and clotted slowly with slow digestion of the clot.

Sensitivity Tests.—Sensitivity tests with Evans "Sentest" tablets on 10% sheep blood agar as basal medium showed the organism to be resistant to penicillin and erythromycin, partially resistant to streptomycin and aureomycin, but sensitive to chloramphenicol, oxytetracycline and tetracycline.

IV. PATHOGENICITY FOR LABORATORY ANIMALS.

The organism was pathogenic in large doses for guinea pigs and mice. Mice inoculated intraperitoneally with 0·1 ml. of a 24-hour broth culture died overnight. A guinea pig inoculated intraperitoneally with 0·25 ml. of the same culture died in 36 hours. The organism in each case was recovered from the liver, lung and spleen of the experimental animal.

In smaller doses mice were susceptible but guinea pigs somewhat resistant.

A mouse inoculated intraperitoneally with 0·02 ml. of a 1/20 dilution (0·001 ml.) of a 24-hour broth culture died overnight. Necropsy showed a focal necrosis of the liver and the organism was isolated from liver, lung and spleen. A guinea pig was inoculated intraperitoneally with 0·1 ml. of a 1/20 dilution (0·005 ml.) of the same culture. There was no evidence of infection in this animal when it was killed fourteen days later. Three other guinea pigs inoculated intraperitoneally with 0·3 ml. of a 1/20 dilution (0·015 ml.) 0·5 ml. of a 1/20 dilution (0·025 ml.) and 0·5 ml. of a 1/10 dilution (0·05 ml.) of a similar 24-hour broth culture were not clinically affected. Fourteen days after inoculation they were killed. Four to six small abscesses of about 1 mm. diameter were found in the liver of each animal. The organism was cultured from these sites in which it had apparently localised.

V. OCCURRENCE OF THE ORGANISM.

Water and soil from a swamp on the Animal Health Station were examined. This swamp is eight miles from the piggery from which the infected animal came and it is on a different water shed.

The muddy water was centrifuged and a sample from the surface of the deposit was sown on 5% glycerol agar and McConkey agar.

Eight samples of water containing varying amounts of soil were examined from this particular swamp and three strains of chromobacteria were isolated.

The three strains isolated from the soil and water (Strains 2, 3, 4) were morphologically similar to the organism isolated from the pig described above (Strain 1). The only variations from the description given for Strain 1 were:—

Strain 2: Acid but no gas was produced in sucrose after 24 hours, weak acid but no gas in maltose after seven days. It gave a weak positive methyl red test.

Strain 3: Acid but no gas was produced in sucrose after 24 hours, weak acid but no gas in maltose after seven days.

Strain 4: Sucrose was not fermented. Weak acid but no gas was produced in maltose after seven days. It gave a weak positive methyl red test. Methylene blue was not reduced.

Pathogenicity tests with mice and guinea pigs gave similar results to Strain 1 but Strain 3 killed a guinea pig overnight when 0·3 ml. of a 1/20 dilution (0·015 ml.) of a 24-hour broth culture was given intraperitioneally.

VI. DISCUSSION.

Sneath (1956) has pointed out the confusion that exists in the classification of chromobacteria. This confusion and the general conception that *Chromobacterium violaceum* is non-pathogenic may have caused some pathogenic chromobacteria to be overlooked. As good growth occurs at 37° C. the organism isolated by us does not fit into Bergey's classification of the chromobacteria. However, it resembles the bacterium described by Woolley (1904), Schattenberg and Harris (1942) and Sneath *et al.* (1953). These articles leave little doubt that *Chr. violaceum* var. *manilae* is pathogenic.

The strain described by us almost certainly belongs to the mesophil group listed by Sneath (1956) as *Bacillus violaceus manilae* Woolley; *Chrombacterium violaceum manilae* Ford; *Chromobacterium violaceum* var. *manilae* Schattenberg and Harris.

It differs from Woolley's organism in that it is a facultative anaerobe while his is recorded as obligate aerobe. The pigment is also said to be slightly soluble in water. In our specimen, mixing of culture and water gave this impression but when the mixture was centrifuged the supernatant remained clear.

Bergey (1948) says that *Chromobacterium ianthinum* may be the same species as *Chr. violaceum manilae*, Ford but *Chr. ianthinum* is described as a bacillus 1·5μ to 5·0μ long with peritrichous flagella. *Chr. violaceum manilae* is a smaller organism with a single flagellum.

The organism described by Schattenberg and Harris (1942) was similar to ours in pathogenicity for mice and guinea pigs. Also, Schattenberg and Harris (1942) described the abscesses in their human case as bizarre-shaped pulmonary and hepatic nodules. In the lesions described by us in the pig irregular-shaped abscesses were a striking feature of the post-mortem examination.

From our observations the organism would appear to be common in the Townsville area but no other cases of infection have become known to us. Therefore, it seems that even though it can cause extensive lesions, the organism only rarely affects animals.

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CHEESE YIELD INVESTIGATIONS

2. THE SAMPLING OF WHEY

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SUMMARY.

A system for the sampling of whey for the determination of fat and casein losses in cheese manufacture has been evolved. The figure for percentage fat content as determined on a sample of whey taken from the surface of the vat must be reduced by 0.045 to obtain the correct result. Such a surface sample, however, gives a fairly reliable value for protein content.

The system may have to be modified according to the method of cheesemaking adopted.

I. INTRODUCTION.

Trials were carried out in an attempt to find a satisfactory method of sampling whey so that fat and casein losses in cheese manufacture could be accurately determined. Exploratory work was carried out at four different cheese factories, and the testing of the method decided upon was carried out at one factory where adequate facilities were available. As this is the factory where the main cheese yield investigations are being made, the results are applicable to this work.

The question of losses in the white whey was not examined in this investigation as it is considered that they can be determined separately.

II. METHODS.

The usual factory method is to take samples from a few different positions at the surface of the whey immediately the stirrers are removed before the whey is run off. As a first step it was decided to check this method against other possible methods.

The following samples were taken:—

(1) From the surface of the vat. A dipperful was taken at 12 places around the perimeter of the vat.

(2) From the whey discharged as soon as the tap was opened. A bucket was placed underneath and a sample taken.

(3) From the whey discharged when the vat was approximately half-empty.

(4) From the whey discharged when the level of the whey was half-way down the orifice.

Investigations were carried out on three vats at each of two factories (A and B). At a third factory (C) an effort was made to ascertain when the drop in fat content occurred, by measuring with a stopwatch the time from the commencement of wheying-off when each sample was taken.

Analyses for fat content were carried out in duplicate on each sample, using the N-butyl-alcohol modification of the Babcock test.

To obtain an accurate assessment of the fat percentage in the bulk whey, in each case the whole of the bulk whey up until the second turning of the curd was pumped into a tank, where it was thoroughly stirred with a curd rake and then sampled. The fat content of this sample is regarded as measuring accurately the fat content of the bulk whey with the exception of white whey. In this manner it was hoped to find out if the difference between the tank and the sample from the surface is constant. If the difference is constant, then an accurate determination of the fat content can be made by applying a correction factor to the result obtained from a sample from the surface of the vat.

As casein losses are also of importance, protein determinations were carried out on samples from six vats. The method used was similar to the A.O.A.C. Kjeldahl method for milk.

III. RESULTS.

(1) Fat Losses.

At factory A, the results shown in Table 1 were obtained.

Table 1.

Fat Content of Whey Taken Progressively During Running.

Sample.	Fat.
	%
Vat 1—1	0·44
2	0·43
3	0·44
4	0·24
Vat 2—1	0·30
2	0·30
3	0·28
4	0·22
Vat 3—1	0·38
2	0·37
3	0·35
4	0·21

Similar results were obtained at factory B but the difference between sample 4 and the other samples was not quite as marked. The results indicate, however, that there was a reduction in the fat content of the whey towards the end of the wheying-off.

At factory C, similar results were obtained for each vat, as shown in Table 2 and further illustrated graphically in Fig. 1.

Fig. 1.

Fat Content of Whey Sampled Progressively During Running.

Table 2.

Fat Content of Whey From Commencement to Completion of Running.

—	Fat.
	%
Whey from the surface	0·36
As soon as cock opened	0·37
3 minutes after	0·36
5 minutes after	0·37
7 minutes after	0·30
8 minutes after	0·22
9 minutes after	0·17
10 minutes after	0·17
12 minutes after	0·14

Similar trends were obtained in a further seven trials at one factory.

The fat percentages of a series of samples during the course of running are shown in Table 3, together with the fat percentage of a sample from the tank. It will be seen that the difference between that from the tank and that from the surface of the vat was 0·04 per cent. Similar results, determined in quadruplicate, were obtained from eight different vats. The difference in fat content between tank and surface samples was always either 0·04 or 0·05 per cent., with a mean of 0·045 per cent.

Table 3.

FAT CONTENT OF WHEY AT VARIOUS STAGES OF RUNNING.

Sample No.	Fat.
	%
1	0·33
2	0·31
3	0·25
4	0·18
5	0·24
6	0·21
7	0·29

The following are particulars of the samples:—

Sample 1.—A dipperful of whey taken from the surface of the vat at 12 places around the perimeter.

Sample 2.—Taken from a bucket placed underneath the tap as soon as it was opened.

Sample 3.—Taken from the tap when the whey was level with the top of the orifice and the vat tipped.

Sample 4.—Taken from the tap when the whey was half-way down the orifice.

Sample 5.—Taken from the tap after the curd was parted.

Sample 6.—Taken from the tap after the curd was turned for the second time.

Sample 7.—Taken from the tank.

(2) Casein Losses.

Casein loss estimations are shown in Table 4.

Table 4.

PROTEIN CONTENT OF WHEY AT VARIOUS STAGES OF RUNNING.

Sample No.	Protein.
	%
1	1·02
2	1·01
3	1·01
4	1·02
5	1·18
6	1·07
7	1·01

It will be noted sample No. 5 was considerably higher than the others. Taking the value for the tank as a basis of comparison, sample No. 5 from the six vats examined was greater than this by the following values:—0·15, 0·14, 0·06, 0·13, 0·09, 0·17 per cent., with a mean value of 0·12 per cent. The differences between samples from the vat surface and the tank were as follows:— +0·02, —0·05, —0·03, +0·01, +0·03, +0·01, with a mean of 0·0 per cent.

Further evidence of the constant rate at which protein losses occur, in contrast to fat losses, is given in Table 5 for bulk whey and white whey from the same vat.

Table 5.

FAT AND PROTEIN PERCENTAGES OF BULK WHEY AND WHITE WHEY FROM FOUR DIFFERENT VATS.

	Fat.	Protein.
	%	%
Bulk Whey	0·36	0·95
White Whey	4·6	1·33
Bulk Whey	0·40	0·96
White Whey	6·4	1·22
Bulk Whey	0·35	0·98
White Whey	6·3	1·40
Bulk Whey	0·33	1·06
White Whey	4·6	1·24

IV. DISCUSSION.

The results indicate that taking a sample from the surface of the whey is unsatisfactory unless some adjustment to the test result can be made. Wide variation occurs in the fat content of whey as wheying-off progresses, the reduction ranging from 0·44 per cent. to 0·21 per cent. It is probable that most, if not all, of the fat is in the whey before wheying-off is commenced. As wheying-off proceeds, the fresh whey continuously expelled from the curd has a very low fat content. This has a dilution effect on the amount of fat originally present and this effect increases as wheying-off progresses.

It appears therefore that a correction factor must be introduced if an accurate estimation of fat losses in cheese manufacture is to be obtained.

The difference between the fat content of the whey in the bulk whey tank and that of a surface sample from the cheese vat was practically constant and in every case was either 0·04 or 0·05 per cent., with a mean of 0·045 per cent. It is therefore proposed to use this figure as a correction factor in fat loss calculations in the main cheese yield experiment at the factory at which the tests were conducted.

There is no case as yet for applying this figure to other factories. In some cases, a difficulty is presented by the practice of running off some whey

and allowing the bulk to stand, thus hoping to speed up acidity development. However, it is considered probable that this will cause no perceptible variation in the correction.

There does not appear to be any significant difference in the casein losses in the whey as wheying-off proceeds and consequently the surface sample gives a reliable measure of the protein content.

The significance of the correction factor for fat content is illustrated by the difference in the estimated fat loss caused by an error in fat estimation of 0·045 per cent.

Consider 100 lb. milk giving 10 lb. cheese and 90 lb. whey. With an average fat content of milk of 4·0 per cent., the weight of the fat in the milk is 4 lb. The error in weight of fat due to an error of 0·045 per cent. in estimating the fat in the whey is equivalent to 0·04 lb.—that is, 1 per cent. As the average fat loss in the whey is about 7 per cent. an error of the magnitude of 1 per cent. is considered of importance.

V. ACKNOWLEDGEMENTS.

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TECHNICAL NOTES

DAMAGE BY ANTS TO PLASTIC SHEATHED CABLES

Following the manufacture of plastic covered cables the Postmaster-General's Department of the Commonwealth Government installed considerable numbers of small polythene sheathed underground telephone cables. During the autumn of 1956 failures in some of these cables, as a result of perforations in the sheath allowing the entry of moisture, were reported from Brisbane and Toowoomba.

The damage consisted of scattered to numerous small surface erosions of varying depth and holes completely penetrating the sheath (Fig. 1). These were mostly circular, with both the erosions and the walls of the holes showing tiny

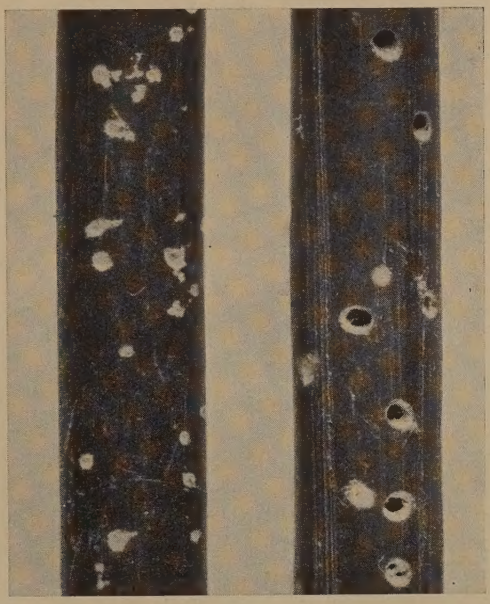

Fig. 1.

Polythene Sheathed Telephone Cable Damaged by Ants. Left, Surface Erosion. Right, Holes Through Sheath.

grooves resembling chewing marks. A study of possible causes of the perforations directed attention to the coastal brown ant, *Pheidole megacephala* (F.), which in large populations was in close association with the cables in each location of the faults.

A trial was conducted to determine whether ants were the cause of the damage, whether current flow influenced attack, and whether damage could be prevented. Installation of experimental polythene sheathed cables was as follows:—

A. One pair cable, connected in parallel with a subscriber's working pair and with open circuit on the distant end.

B. One pair cable, unconnected, with conductors open circuit at each end.

C. Two pair cable, with conductors looped at the distant end and connected to battery and earth at the exchange to allow a 40–50mA. current flow.

D. One blue and one orange-coloured single wire, with conductors open circuit at each end.

E. One black and one white single wire, connected in parallel with a subscriber's working pair and with open circuit on the distant end.

A, B and C were black cables.

A and B were replicated four times, namely in the Brisbane suburbs of Clayfield, Sunnybank and Windsor and at Toowoomba. C was installed at Clayfield only and D and E at Windsor. The cables varied from 20 to 40 ft. in length and were buried approximately 6 in. apart. The dates and depths of installations were:—Clayfield, June 1956, at 6 in.; Sunnybank, July 1956, at 12 in.; Windsor, October 1956, at 8 in.; and Toowoomba, November 1956, at 8 in.

At each site an area 8 ft. long and extending for 6–12 in. on each side of the cables was sprayed at cable depth with 2·0 per cent. chlordane (80 per cent. W/V miscible oil diluted with water); elsewhere the cables were untreated. Relevant details and results of examinations were as follows:—

Clayfield.—On Dec. 18, 1956, light damage was recorded on all cables in the untreated area, where *P. megacephala* was present in considerable numbers. No damage and no ants occurred in the treated area. By Apr. 16, 1957, extensive damage had occurred on cables B and C and light damage on cable A in the untreated area. Very light damage appeared on cables B and C in the treated area, while ants were in moderate numbers in both untreated and treated areas.

Sunnybank.—On Dec. 18, 1956, moderate damage was present on both cables A and B in the untreated area, where *P. megacephala* was common but not numerous. No damage and no ants occurred in the treated area. By Apr. 16, 1957, severe damage had occurred in the untreated area, with light to moderate damage in the treated area, and ants were present in small numbers in both places.

Windsor.—On Feb. 18, 1957, no damage had appeared on any of the cables and *P. megacephala* was present in small numbers in the untreated area only. By Apr. 17, 1957, light damage had occurred on both cables A and B and moderate damage on each of the coloured cables of D and E in both untreated and treated areas, with ants present generally in large numbers.

Toowoomba.—On Jan. 21, 1957, light damage was present on both cables A and B in the untreated area and none in the treated area; the same results were observed on May 17, 1957. *P. megacephala* was recorded at this site prior to the installation of the cables.

These results indicate that the coastal brown ant, *Pheidole megacephala* (F.), was responsible for damage occurring within a few months on differently coloured underground polythene sheathed telephone cables whether carrying continuous, intermittent or no current. Chlordane as a 2·0 per cent. spray in an area surrounding the cables at cable depth afforded only temporary protection.

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CONTROL OF THE CEDAR LOOPER

During an insecticide trial against the cedar shoot borer, *Hypsipyla robusta* (Moore), at Imbil in 1955, newly established plantation trees of red cedar (*Cedrela toona* Roxb. var. *australis* (F.Muell.)C.DC.) were attacked by larvae of the cedar looper, *Pingasa* sp. (Geometridae), and some trees were severely defoliated (Fig. 1.).

Fig. 1.

Small Red Cedar Tree Almost Defoliated by Looper Larvae.

The trial was a 15 x 4 randomised block, with a unit plot of 50 trees. Spraying was carried out according to programme from Mar. 1 to May 16. In late May counts of trees damaged by the cedar looper were made and, using ratings from 0 to 4, defoliation of each tree was assessed. At this time the trees averaged 1 ft. 6 in. in height. Treatments and results are given in Table 1; unless otherwise indicated the insecticides were emulsifiable concentrates.

Table 1.

TREATMENTS AND MEAN VALUES OF LOOPER DAMAGE.

Treatment.	Interval Between Applications. (Weeks.)	Percentage of Damaged Trees.		Mean Damage per Tree.
		Transformed Mean (Inverse Sine).	Equivalent Mean %.	
1. DDT 0·1%	2	21·2	13·0	0·22
2. DDT 0·2%	2	14·0	5·8	0·13
3. DDT 0·2%	4	29·6	24·4	0·30
4. DDT 0·2% [1]	2	11·2	3·7	0·06
5. Endrin 0·025%	2	7·6	1·7	0·08
6. Endrin 0·05%	2	5·4	0·9	0·02
7. Endrin 0·1%	2	8·6	2·2	0·03
8. BHC 0·03%	2	40·3	41·8	0·57
9. Dieldrin 0·05%	2	25·8	18·9	0·22
10. Lead arsenate 1 lb./20 gal. [1] ..	2	44·9	49·9	0·56
11. DDT 0·2% + white oil 0·8% [2] ..	4	24·9	17·7	0·24
12. Lead arsenate 1 lb./20 gal. + white oil 0·8%	4	53·1	63·9	0·88
13, 14, 15. Untreated	..	47·7	54·7	0·82
Necessary differences for significance: Treatment Means 5%		16·1	..	0·32
Treatment Means 1%		21·5	..	0·43
Untreated v. Treatment Means 5%		13·1	..	0·26
Untreated v. Treatment Means 1%		17·6	..	0·35

[1] Wettable powder. [2] Emulsion concentrate.

These results show that both endrin and DDT gave outstanding protection to young red cedar trees against looper attacks, and should this occasional pest become troublesome a suitable control could be achieved.

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